Module Measurements at LBL

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Brief history of LBL-built pixel modules

- Summary of this work, from the beginning...

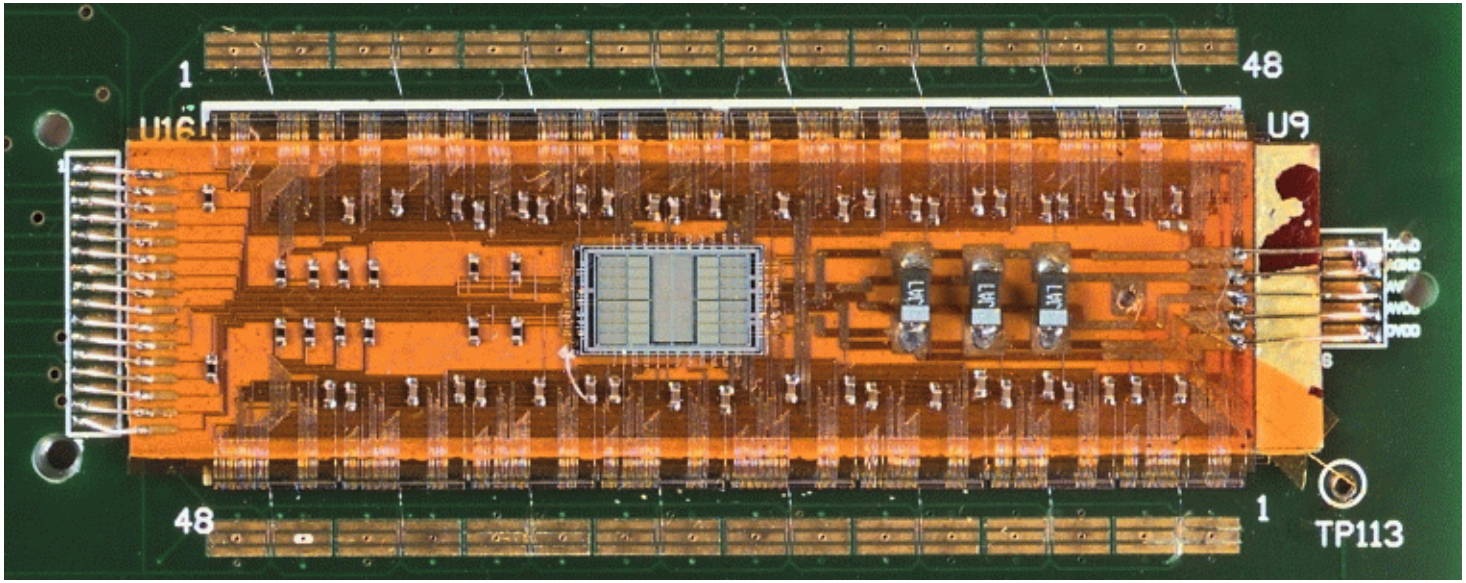
New module measurements:

- Received first batch of Flex 1.1, and two IZM SSGb modules in August.
- Received new batch of Flex 1.1 and another IZM SSGb module in October.

Initial FE-B Module Construction

First three FE-B modules were built by Boeing:

- First two modules were received in June 98. They were built up as bare modules using the first Genova support card. First test results were available in Sept. 98, and showed many problems with noise and stability.
- Third module, made with 150μ thick die, was built using Flex1.0 and tested in Nov. 98, and showed similar noise and stability problems. Indications from single chips were that there was a significant problem with Boeing bump resistance.
- All three of these modules had all 16 FE chips working perfectly under digital testing.



First generation of IZM FE-B modules:

- First two IZM FE-B modules received in Feb. 99, and were built with FE-B Wafer #22. Unfortunately, the Tile2 module broke in transit to LBL. The Tile1 module was built up as a bare module with the new Genova support card including the Hitbus OR logic (so-called M1). It worked extremely well, but had an intermittent short in the XCK distribution, which caused the card to fail within a few months. This first module had many solder bump problems (bridges, etc.), but otherwise performed as well as the best single-chip assemblies we have made.
- Second two IZM FE-B modules received in Apr. 99, built largely with FE-B wafer #14 die (back-side plated with 5000A of Au). One module sent to UOK (Tile2, mixed electronics die), and the second (Tile 1, all back-side plated die) was built up using Flex1.0 (so-called M2). This module worked well in the lab, but the threshold dispersion was larger than M1, and tended to drift by a few hundred electrons between threshold scans. After testing in H8 in May and July 99, it was discovered to have “delaminated” in Sept. 99, with only the middle four chips continuing to be connected to the sensor. This was almost certainly a result of thermal stress introduced during construction (module was attached to Al support plate with rigid conductive epoxy which was then cured at about 80 C), followed by solder creep and eventual failure (see Gil’s talk in this meeting).
- Both of these modules had all 16 FE chips working perfectly.

- Additional two IZM FE-B modules received in July 99. One sent to UOK, one remained at LBL. In process of first testing of module probing setup, we realized that there were FE-B die used in the module which had never been probed, and therefore could not have been known good die. We failed to test this module on the probe station because of the contamination film present on wire-bond pads after IZM bumping (see KFE talk on bond pad analysis). This module has never been built up with a support card.
- As a result of this early experience, IZM now provides excellent documentation of the sensor and FE die used in each assembly, as well as X-ray bump verification with the number of faults of each type which occur on each FE die in the assembly. This is extremely valuable, and should be continued from now on.

Results from recent IZM FE-B modules with Flex 1.1:

First attempt made using "prototype assembly procedure":

- Received two identical FE-B modules using SSGb tiles from IZM in Aug. 99, which had been built using die from FE-B wafer #10.
- Attempted to assemble these into Flex modules using prototype assembly procedure, including Araldite 2011 epoxy Flex attach, and CGL7018 Cool-Gel plus CEA123 UV-cure epoxy module attach. Unfortunately, first Flex1.1 batch had serious trace adhesion problems which were only discovered after epoxy attach. One of the two modules was destroyed in trying to remove defective Flex.
- Second module was successfully assembled using Thermagon phase-change polymer film (Tpcm-705) Flex attach (this material is re-workable). The best Flex1.1 was chosen, and the trace adhesion problems did not cause any fatal assembly problems (but some significant bricolage was needed).

Testing of this module indicated serious problems:

- Nine chips worked OK with digital injection, while seven chips fail to pass this basic functional test.
- There do not appear to be any Support Card or Flex connectivity problems. There are some indications of one MCC problem. Other problems seem clearly related to the FE chips themselves, which were probed on their bond pads for testing.

- **Chip #0:** passes register tests, but produces data corruption errors. As soon as the first L1 arrives at the chip, it produces a very long stream of data, among which some real hits are buried. This suggests a strange failure in the chip readout controller.
- **Chip #2:** has a single stuck-on bit in the DAC register, but the Pixel Register is OK. During digital injection, it returns only EOE words.
- **Chip #3:** passes all register tests. No data is transmitted under digital injection, not even the minimum of the EOE words.
- **Chip #4:** strange bit errors are seen during the register tests. The Pixel Register test appears to produce an output which is shifted by 30 bits relative to the input. Digital injection is dead, and no EOE words are transmitted after L1 is sent.
- **Chip #5:** passes all register tests. No data is transmitted under digital injection, not even EOE words.
- **Chip #10:** Dead for all register tests. DO pads on FE chip show full CMOS swings (even on MCC bond pads), indicating an apparent broken termination resistor in the MCC. It is possible that replacing the MCC would cure this problem.
- **Chip #14:** dead for all register and digital inject tests.
- We have never even seen errors of this type during wafer probing. Also, all die used (according to IZM documentation) were known good die. All die were verified to have probe marks on their pads prior to wire-bonding. This suggests a significant change occured in IZM bumping processing...

Second attempt with modified procedure:

- Received a final FE-B module built with an SSGb sensor and FE-B wafer #7 die in Oct. 99. This module was built up using Thermagon Tpcm-905 film for the Flex attach, and the CGL/CEA low-modulus technique for the module attach step.
- No major problems were encountered during assembly.

Testing of this module also showed significant problems:

- **Chip #0:** Register test has bit errors, although all signals on FE die look OK.
- **Chip #1:** passes register tests. No EOE words are produced during digital injection.
- **Chip #2:** completely dead. All pads were checked. LVDS output driver for DO has correct DC levels for “zero” data. All other pads looked OK (CCK, DI, LD, GA, all power supplies and grounds, XCK, LV1, SYNC, RST).
- **Chips #8 and #9:** occasionally work properly under digital injection. Normally fail register tests and produce no data under digital injection.
- All working FE pass registers tests in both transparent and full MCC mode. Digital injection works in transparent mode, but causes data corruption errors, and MCC F1 and F5 errors, in full MCC mode. This suggests that there is a significant fault within the MCC, since MCC mode uses a subset of the external connections used in transparent mode.

Summary of FE-B wafers and IZM

History of wafers sent to IZM (total of about 800 good die):

- First sent Wafer #22 in May 98
- First back-side plated wafer #14 sent in Dec. 98
- Wafers #12 and #17 were sent in Mar. 99
- Wafers #9 and #10 were sent in June 99 (customs problems delayed arrival for more than 3 weeks).
- Wafers #7 and #8 sent in July 99
- Wafers #5 and #6 sent in Sept. 99

Remaining FE-B wafers:

- Wafer #15 (back-side plated) and Wafers #1 and #3 are all that remain.
- They are all being tested now by John. I propose that we reserve one for Sofradir, and send the other two to IZM. However, I would propose not to send them until the remaining technical issues with IZM are resolved in our Dec. meeting.
- I believe the last two wafers we sent to IZM (#5 and #6) have not yet been processed, and I would propose that processing of these wafers also waits for resolution of remaining technical issues.

Summary

- Despite excellent initial progress early in 99, there seem to be serious problems that inhibit further progress in module prototyping.
- Module probing as soon as the assemblies arrive from IZM is critical to an efficient production sequence. This seems to be impossible until bond-pad contamination problems are fixed.
- Starting with modules received in August, new modules have significant electrical problems which are statistically incompatible with our earlier experience with both Boeing and IZM. This problem could have started earlier, but since the July module was assembled with bad die, no conclusions can be drawn about that period. The last good module was received in April.
- There are not so many remaining FE-B die, and given the problems with FE-D, it is critical for us to manage what is left very wisely. We need to resolve the two problems above very urgently, and keep enough FE-B die around to verify the solutions, otherwise we risk losing a very significant amount of time in module prototyping afterwards.
- One goal of this summer's program was to build at least three identical modules, one bare and two Flex. The two Flex were to have minimal and maximal decoupling. The Flex were to be tested with power cable prototypes for noise comparisons, as well as studied in the testbeam, which is critical for proving we meet our electrical performance specs. This is now significantly delayed...